The Open University

S102PRP/S510 MODULE 3 INTO SCIENCE

MODULE 3 LOOKING AT BUILDINGS

THE INTO SCIENCE COURSE TEAM:

CHAIRS
Judith Metcalfe
Alison Halstead

GENERAL EDITOR
Judith Metcalfe

AUTHORS
Bob Cordell (Staff Tutor, East Midlands Region)
Dee Edwards (Department of Earth Sciences)
Alison Halstead (Staff Tutor, West Midlands Region)
Judith Metcalfe (Staff Tutor, West Midlands Region)
Dave Williams (Department of Earth Sciences)

EDITOR
Clive Fetter

CONSULTANTS
Mark Atlay (Centre for Science Education)
Stuart Bennett (Department of Chemistry)
Jane Nelson (Staff Tutor, Northern Ireland)
John Walters (Staff Tutor, Wales)
Ruth Williams (Staff Tutor, South West)

OTHERS WHO HAVE HELPED WITH PRODUCTION
Debbie Crouch (Designer)
Perry Morley (Senior Editor)
John Taylor (Illustrator)

FRANCHISE CO-ORDINATOR
Alison Halstead

OTHERS WHO CONTRIBUTED TO EARLIER EDITIONS
Trevor Brown (Part-time Tutor, West Midlands)
Sharon Buckley (Bournville College of Further Education, Birmingham)
Anne Kavanagh (Wulfrun College, Wolverhampton)
Martin Lissenburg (Part-time Tutor, West Midlands)
Claire Nelson (Illustrations consultant)
Gwen Parsons (North Warwickshire College of Technology and Art, Nuneaton)
Nick Studdert-Kennedy (Illustrations consultant)
Peter Turner (Illustrations consultant)
Richard Williams (Part-time Tutor, West Midlands)

The Open University, Walton Hall, Milton Keynes MK7 6AA.

The course was developed in the West Midlands Region and first published as a pilot project in 1991. Revised 1992, 1993.

Edited, designed and typeset by the Open University.

Printed in the United Kingdom by Page Bros, Norwich.

ISBN 0 7492 5113 1

This text forms part of an Open University Foundation Course. If you would like a copy of *Studying with the Open University*, please write to the Central Enquiry Office, PO Box 200, The Open University, Walton Hall, Milton Keynes, MK7 6YZ. This text is also part of an Access Pack. For further information on Open University access study packs, write to Central Enquiry Service, PO Box 280, The Open University, Walton Hall, Milton Keynes MK7 6YZ, requesting the Community Education brochure.

3.1

STUDY GUIDE

This Module looks at some aspects of buildings, the materials of which they are made and also their size and shape. It begins (Sections 2 and 3) by looking at some traditional building materials, such as stone, and shows how the types of building stone used differ, depending on where you live. You will discover the age and type of building stone or rock in your locality. It may surprise you to learn that such a great variety of rocks occurs in what is the relatively small area of Britain and Ireland. The processes involved in the formation of rocks (Section 3) may be totally new to you, but we hope that you will find the Section an interesting read. There will be unfamiliar terms, particularly names of rocks *but you are not expected to remember these*. Many places are mentioned, but having completed your study of Section 3 you can relate your knowledge to the rocks and building materials in your locality, or areas you visit. Knowledge in this area of science will give you a better understanding of your environment.

When you have finished studying Sections 2 and 3 you should understand:

- the origin of rocks
- that by looking at buildings it is often possible to work out where the materials used to construct them have come from.

However, describing a building not only includes knowing about the materials of which it is made but also its size, such as area and volume, and its shape, such as squares, rectangles and triangles. So, in Section 4 you will have an opportunity to make some measurements of a room. For this you will need a measuring tape marked in metres, centimetres and millimetres. (A retractable metal tape-measure—the type that rolls in and out of a small case—is ideal; alternatively a cloth tape-measure will do.)

So that you can get some practice in and feel confident about approaching problems involving numbers, Section 4 involves some arithmetic, mainly multiplication and division, using decimals. There are often several different ways of working through problems and, although some ways may be better than others, sometimes there is no 'correct' way. Do not get disheartened if you have tried to solve a problem in a way that is different from the way we suggest; provided that you arrive at the same answer, your way is fine. If your answer is different, then you need to check again, or ask for advice from your tutor or other students.

The study skills in this Module reinforce and extend the skills introduced in the two previous Modules; in particular practising the technique of highlighting important words, phrases or sentences, using a highlighting pen.

You should expect to spend around four hours studying this Module, but this will depend on your experience of studying and doing mathematics. You may take longer, but you will find that you become a more efficient learner and get nearer to the estimated times (given in Module 1) when you reach the later Modules.

1 USING A HIGHLIGHTING PEN

Reading can sometimes be a rather passive process. One way to think about the text as you read is to continually underline or highlight words and phrases with a pen as introduced in Module 1. This technique is straightforward, and many students find it a useful and effective method of summarizing, or reviewing the work that they have done. When you read a paragraph of text, use a highlighting pen to emphasize the words or phrases that appear to you to be most important, i.e. those that carry the crucial explanation of a point, or a definition. These would constitute the information that you would need when writing a summary of a paragraph, or passage of text in your own words. Having done the highlighting, your eyes will be drawn to the points and phrases that are the most important next time you read the text.

What you choose to highlight, and how much, rather depends on you. At first you might be tempted to highlight everything, and, very occasionally, whole paragraphs may be important enough to warrant this. However, in the following text, this will not be necessary and you should look for short words and phrases that are worth highlighting; it is easier to add another highlighted phrase later than to delete highlighting. Try to be selective and remember that in these first Modules you will not be bombarded with important facts. So your highlighting pen is unlikely to get over-used; try to save some ink for later Modules!

We have provided an example to get you started. To gain some practice in this technique, read the next Section, using your highlighting pen to pick out words and phrases relating to *building materials*, and check whether the words or phrases you have selected match ours. Such highlighted phrases can be used to write a short summary about building materials.

In addition to highlighting you may want to make notes in the margins. You may also want to write down a question or an example, or something to jog your memory. All these activities help maintain your interest in reading by helping to:

- focus your attention
- make reading an active process
- aid revision, by helping you to scan the text when you return to the material.

2 BUILDINGS THROUGH THE AGES

This Section shows how over the ages the material from which buildings are made influenced their shape and structure. It sets the scene for Section 3 which looks in more detail at what is a building stone. There is an SAQ about highlighting at the end of this Section; it would be useful to read it now before studying the Section.

FIGURE 1 My home—1000 BC.

What might your home have looked like if you were reading this in 1000 BC? In most areas of the Midlands, and the south-east of England, the majority of houses were built of timber, with a straw or turf roof, on a wooden framework (Figure 1). Gaps in the timber walls might have been filled with dried mud. Houses of this type have been built throughout history and can still be found today, in countries as far apart as Bangladesh and Brazil. Timber is still the main building material in, for example, the mountain states of the USA and Canada.

In 1000 BC, in the north and west of England, in Scotland and parts of Wales, your house might have been made from stone, with a roof of stone or turf, supported on a wooden framework. The stone was likely to have been obtained locally, as it was time-consuming and tiring to bring heavy building materials long distances. In those times you would most probably have been a farmer, with animals to protect; to stop them from straying, you would have collected stones from your fields and used them to build your field walls, in addition to the

walls of your house. The walls of groups of houses of local stone, with stone beds and stone furniture dating from 6000 BC to 2000 BC still survive in the Orkney Islands and in the far west of Cornwall. None of the roofs have survived.

The Romans (55 BC to AD 410) introduced new materials and advanced techniques of building construction during their occupation (Figure 2). Mosaic tile floors (made from clay, baked at high temperatures) survive at many Roman sites, as do bricks, roof tiles and pottery made by similar methods. One of the reasons why the Romans could use bricks was because they had discovered how to make mortar (a mixture of sand and cement that sets hard) to hold the bricks together in a rigid structure. Underfloor conduits carried hot water and steam, for heating—an innovation that was to disappear for nearly two thousand years after their departure. Houses in the north continued to be made of local stone, as were, for example, square forts and mileposts, and the massive bulk of Hadrian's Wall. Centres of population, such as London, York and Bath, were connected by roads paved with stone, so that they could withstand their constant use by horses, carts and marching feet.

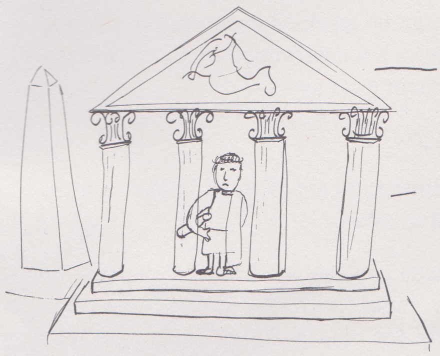


FIGURE 2 A Roman building of about AD 400.

After the departure of the Romans, domestic buildings were once again made of timber and other natural materials.

□ Can you think why there are so few examples of buildings that date from before the Norman Conquest (1066)?

■ Many buildings burned down—heating, lighting and cooking made use of open fires and candles, so that a building being set alight was an ever-present danger. Also, timber and turf rot away to become part of the soil, so their remains are not seen.

By the Middle Ages—roughly from the coming of the Normans (1066) to the accession to the throne of Elizabeth I (sixteenth century)—people regularly made important buildings, such as castles (Figure 3), churches and abbeys, of more durable materials, such as stone.

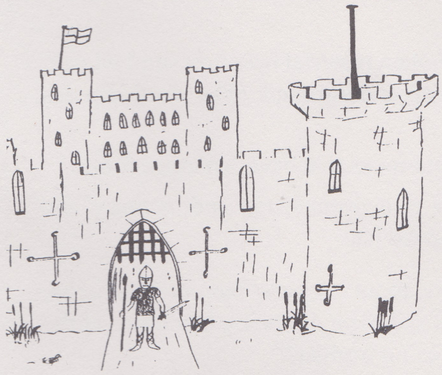


FIGURE 3 A Norman castle of about AD 1067.

Styles of building reflected changes in society. From a life lived at subsistence level, where each family grew or collected its own food, society had developed. It was now possible to produce a surplus of food—necessary, for example, to support the teams of builders and masons that were involved in the construction of huge projects, such as Westminster Abbey and Durham Cathedral. Although local stone was used, there was also a trade in foreign stone: William the Conqueror was particularly fond of the stone of his home region of Caen in Normandy.

In the countryside, houses dating from the seventeenth century have survived. Although some of these are made of local stone, often from a small quarry within a few miles of the village or town, brick was also popular, particularly in the Midlands, south and east, where there is little good building stone available locally.

What exactly is a building stone? Why is good building stone found in some areas of the British Isles and not others? To answer this we need to look at types of stone or 'rock', and the localities in which they are found. This is the topic of the next Section.

SAQ 1 Which words and phrases in Section 2 have you highlighted about building materials in relation to each period of history? Check your highlighted words against the ones suggested in the answer at the back of the Module.

Remember that there are no hard and fast rules; you must develop study skills that you feel happy with, and this takes time and practice. There is a similar exercise for you to try later in the Module so that you can check your progress with this technique. Meanwhile you could continue to highlight words and phrases in the Sections that follow.

3 NATURAL BUILDING MATERIALS: ROCKS

This Section looks at how different **rocks** can be grouped according to the way they were formed. The characteristics of rocks are determined by the process of formation, their composition and to some extent their age.

□ Can you think of the names of any rocks?

■ Slate, marble, granite, sandstone and limestone are all rock names that are commonly used; you may have thought of others.

The Earth is made of rocks. Rocks can be seen exposed in cliffs and quarries, on moorland and beaches. They are infinitely variable: some are very hard (their resistance to hammering makes them useful for road-making); others are very soft (they can be moulded with the fingers, like clay, which makes them good for brick-making); some are light in colour and some are dark; some are fine-grained and others are coarse-grained. To assist your understanding of both rocks and rock-forming processes, a few important rocks and minerals that are reasonably common as building materials are described below.

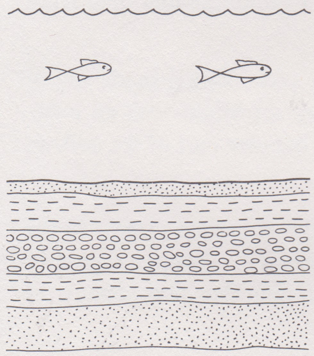


FIGURE 4 Layers of sediment, the raw material of a sedimentary rock.

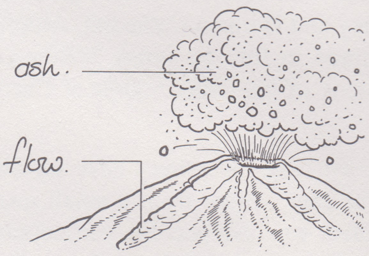


FIGURE 5 Igneous rock is formed from volcanoes.

Most rocks are made up of **mineral** particles (minerals are naturally occurring materials)—for example quartz, which is found in many rocks. Rocks are usually formed from several different minerals, though they may consist almost entirely of one mineral. Rocks are usually classified by the way in which they were formed. On this basis there are three groups of rocks:

1 **Sedimentary rocks**—these are laid down as sediment in layers (for example sand on a beach, or mud on a river-bed) at the surface of the Earth, as a continuous process (Figure 4).

2 **Igneous rocks**—these are formed as molten material becomes solid when it cools, either at the surface (Figure 5) or deep underground. (The word igneous comes from the Latin ignis: 'fire').

3 **Metamorphic rocks**—these are existing rocks that have 'changed form'.

For the moment concentrate on the first two groups, the sedimentary and igneous rocks; metamorphic rocks are discussed later.

□ Are there any processes that you know about, or have seen on television, that make you believe that (a) layers of sediment are being laid down at the present time and (b) igneous rocks are being formed?

■ (a) Rivers often deposit mud (sediment) at their mouths where they reach the sea. The whole of the country of Bangladesh exists on the sediments of the delta of the rivers Ganges and Brahmaputra, which are extending into the Bay of Bengal. (b) There have been recent volcanic eruptions, for example, in 1991 in the Philippines and Mount Etna in 1992; you may also have come across the well-known volcanoes in Hawaii, which are almost constantly active and form a major tourist attraction.

Similar processes have been going on throughout history; even before humans evolved on this planet, igneous and sedimentary rocks were being made, for example by volcanoes and rivers. Look now at where some of these rocks are found in the British Isles, using a geological map of Britain and Ireland.

3.1 A GEOLOGICAL MAP: AGES OF ROCKS

The boxes on the left all represent different types of rock, and the map shows where these types of rock are found. The pattern in the box is called the 'ornament'. The numbers that line up with the boxes tell you how old a particular type of rock is, in *millions of years;* or, put another way, how many millions of years ago that rock was formed.

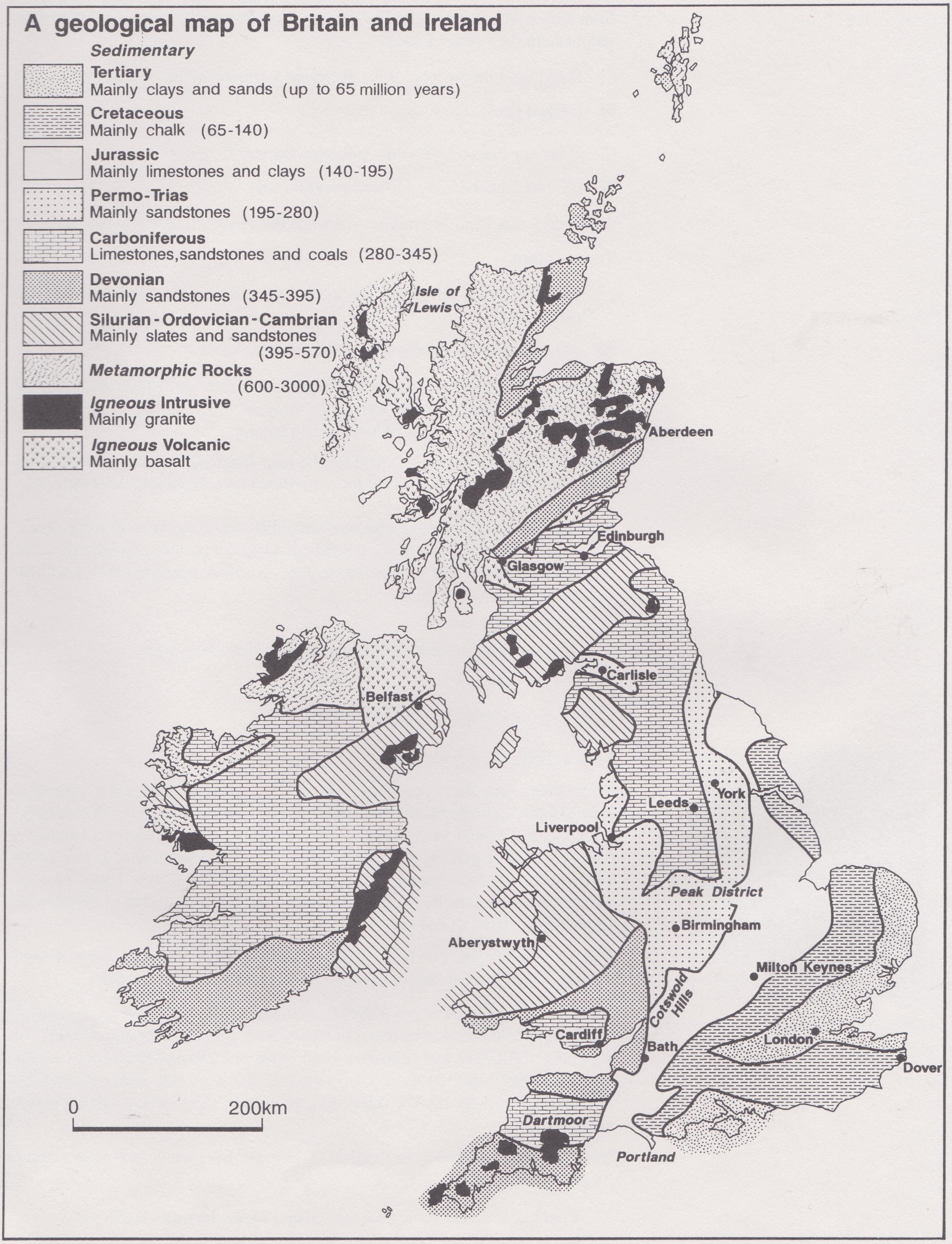


FIGURE 6 A geological map of Britain and Ireland. Names mentioned in the text are marked on this outline map.

Let us look at an example. You may have travelled to the Continent on a ferry from Dover and so have seen the White Cliffs. These cliffs are made of a white sedimentary rock called **Chalk**.

□ Find Dover on the map. What ornament is shown on the map there?

■ Dashed lines

□ What age lines up with this, alongside the map?

■ 65–140. That is, 65 to 140 million years old.

This means that 65 to 140 million years ago the Chalk was being laid down.

Try one more:

□ Find the Isle of Lewis, off the north-west coast of Scotland. How old are these rocks?

■ These rocks are between 600–3 000 million years old.

The rocks in Lewis are very old; they are not the very oldest to be found anywhere on Earth—there are rocks around 3 750 million years old in Greenland—but they are the oldest rocks in Britain.

SAQ 2 Locate your nearest town on the map. How old are the rocks beneath the town? Determine whether the rock is sedimentary, metamorphic or igneous.

Sections 3.2–3.4 go on to discuss the three different rock types in more detail. Rocks from several regions are described, to enable you to consider those in your own locality. What is important is that you finish Sections 3.2–3.4 with an understanding of:

- the origin of rocks
- the differences between the three groups of rocks described.

3.2 SEDIMENTARY ROCKS

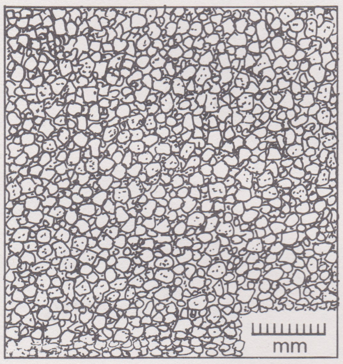


FIGURE 7 A sandstone from Yorkshire.

Look at Figure 7, a sandstone.

Sedimentary rocks have been formed by the 'laying down' of layers of sediment, for example, as material that has been carried in rivers or seas. The material settles to the bottom in the same way as sediment settles to form a layer in a bottle of wine, a glass of beer, or a coffee cup. The processes of laying down sediment can be seen operating today in rivers and on beaches. Large areas of Britain are underlain by sedimentary rocks, such as **sandstones** (Figure 7), **limestones** (Figure 8) and **clays**.

You can see that the rock is made up of small particles or grains of the mineral **quartz**, which is what sand is made up of—hence the name *sand*stone.

The origin of this rock is not difficult to imagine: first the sand (together with a few pebbles) is carried in a stream of water, such as might be found in a river or on a beach. The sand and pebbles are laid down and later the spaces between the grains are filled up. Further deposits are laid down on top, and gradually the sand and pebbles are buried. Over time, all the particles become stuck together to form a rock.

This sample in Figure 7 was collected recently from an active quarry about 15 km north of Leeds.

□ Find Leeds on the geological map. How old are the rocks in this area?

■ They are 280–345 million years old.

The rock in Figure 7 is called Millstone Grit. (*You need not remember these names.*) It was given this name because it was used to make millstones for grinding corn to flour.

FIGURE 8 A limestone from Derbyshire.

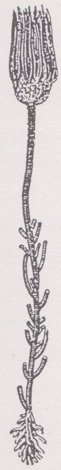


FIGURE 9 A sea lily.

In the nineteenth century, many public buildings were constructed using sedimentary rocks, as they are relatively easy to cut from a quarry, and can be made to look most impressive. Millstone Grit is common in the Pennines, and the rock is clearly visible in the road cuttings on the M62 between Leeds and Manchester. It is a pale-coloured sandstone that was used to build many town halls in the north of England—which have since turned black from the effects of 100 years of soot. Many towns and cities in Yorkshire and Lancashire have houses and other buildings dating from the Victorian era that are constructed of Millstone Grit.

Now look at Figure 8, which is a different rock: a limestone from Derbyshire.

The rock is full of **fossil** fragments. Fossils are the remains of organisms, such as plants and animals, or traces of them, such as footprints. The fossils in this rock are the remains of extinct sea animals called sea lilies, or crinoids. When alive they had a small cup-shaped head with tentacles, but also a long stalk made up of circular plates, which attached the animal to the sea floor (see Figure 9).

All the skeleton was made of the mineral **calcite**, laid down by the animal as it grew. Many of the animals on the sea-shore today, for example cockles and mussels, have shells made of calcite. Calcite contains calcium; you probably know that humans have calcium in their bones and teeth. The material sticking the rock together also consists of a fine calcite mud which settled in between the broken fragments on the sea floor, and has since hardened so that the fossil fragments are stuck in the rock very firmly—so much so that the rock can be cut and polished without the fragments falling out.

The rock in Figure 8 came from the Peak District, in Derbyshire; on the map it is located at the southern edge of the area that is within the same age span as the sandstone in Figure 7. This limestone is the main rock responsible for the spectacular upland scenery of Derbyshire and the Yorkshire Dales. Limestones are extremely important rocks, as they are the main raw material in the manufacture of cement.

Limestones have been extensively used for building. The Whitehall limestone quarry of the Cotswolds gave its name to a street in London, because most of the quarry ended up here! It is similar to the famous Portland Stone from Dorset, a limestone that was used in the construction of St Paul's Cathedral (Figure 10), and which is still widely used to give modern buildings a white 'skin'. The elegant crescents of Bath are built using a local cream-coloured limestone that is similar to the famous Caen stone favoured by William the Conqueror.

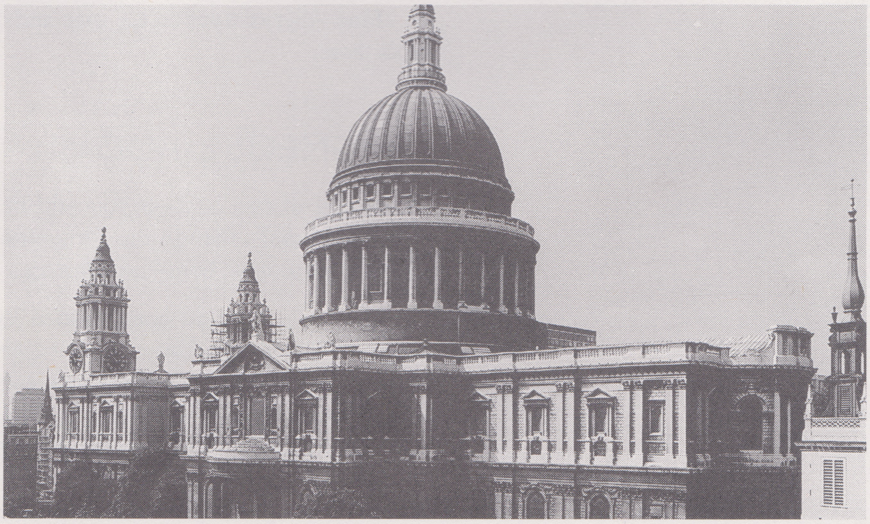


FIGURE 10 St Paul's Cathedral, built of white limestone called Portland Stone.

Some of the buildings of Birmingham, Liverpool and Carlisle are made of the red-brown sandstone shown in Figure 11. The rock is sometimes visible in road cuttings, for example on the M5, south of Birmingham.

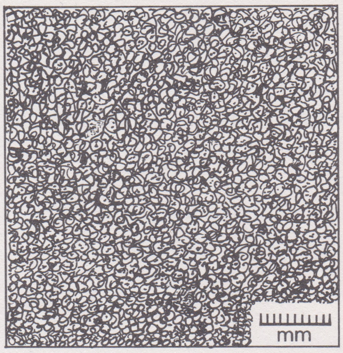


FIGURE 11 A red-brown sandstone.

□ Find Birmingham, Liverpool and Carlisle on the map. All these cities are built on rock of the same type and age. What does the map tell you about the rock's age?

■ The rock is 195–280 million years old.

These cities are built of sandstone that has a much finer grain size than the Millstone Grit shown in Figure 7. In fact, these red-brown rocks have all the characteristics of sands laid down in a *desert*, with very rounded grains stuck together by an iron compound (which gives it its red colour—think of it as being similar to rust). So, 200 million years ago Birmingham, Liverpool and Carlisle were experiencing desert conditions, indicating that Britain has previously undergone at least one severe climatic change.

Pre-nineteenth century domestic building was frequently in local stone, hence the honey-coloured limestone houses of the Cotswolds. Field walls are also a good indicator of local rocks as farmers rarely carried large stones for great distances! Even bricks in older buildings can be traced to different kinds of local clay used in their manufacture.

Most people in England live on sedimentary rocks originally laid down as loose sediment some time in the last 500 million years, as shown by the ages associated with the boxes on the map. In general, the younger the rocks, the softer they are and the more easily they break up.

□ In general, are younger sedimentary rocks more suitable or less suitable than older rocks for use as building stones?

■ In general they are less suitable, as they are softer and more easily broken up. A good building stone needs to be hard and durable.

Older sedimentary rocks (for example, the limestone from Derbyshire shown in Figure 8, which is 280–345 million years old) make better building stones than younger rocks, such as Chalk (65–140 million years old), which is a soft, white limestone. The younger, less suitable rocks are found in the south and east of Britain and the older, more durable rocks in the north; this is one reason why more buildings were made of stone in the north.

SAQ 3

(a) Find the city of Bath, the Cotswold Hills and Portland on the map. What is the age and description of the rocks in this region?

(b) Find Aberystwyth on the map and determine the age and description of the rocks there.

3.3 IGNEOUS ROCKS

At the end of this Section you will be asked to check the phrases you have highlighted that relate to the formation and nature of igneous rocks. Look at SAQ 4 (p. 10) now, before reading on.

Igneous rocks have all been formed by the cooling of hot liquid rock called **magma**—this is called **lava** when it emerges in liquid form from a **volcano**. You may have seen volcanoes in popular science programmes on television. Recently Mount Etna in Italy erupted, with lava threatening the surrounding area. Volcanoes provide evidence that the interior of the Earth is hot—hot enough to melt rocks, at around 800–1 200°C. The cooling process is called **crystallization** because the liquid rock cools to forms crystals. The process is similar to what happens when fudge or toffee 'sets': when the rock is very hot, it is fluid and runny, but as it cools its particles interlock and it becomes a solid. If the lava contains a lot of gas it may crystallize into a rock containing gas bubbles.

□ Do you know of a rock containing gas bubbles that is often found in people's homes (frequently in the bathroom)?

■ Pumice is a volcanic rock containing gas bubbles.

You are unlikely to be able to see igneous rocks being formed; there are no active volcanoes in Britain at present, and in fact igneous rocks are rather rare in England. People living in the north of England, Scotland and Ireland are luckier in this respect (see the key on the map). Volcanoes produce rocks called *extrusive*, formed by the extrusion, or forcing out, of hot liquid rock on to the Earth's surface. Most igneous rocks, such as granite, however, are formed deep underground; these are called *intrusive*, as they are forced into existing rocks. Figure 12 illustrates these points.

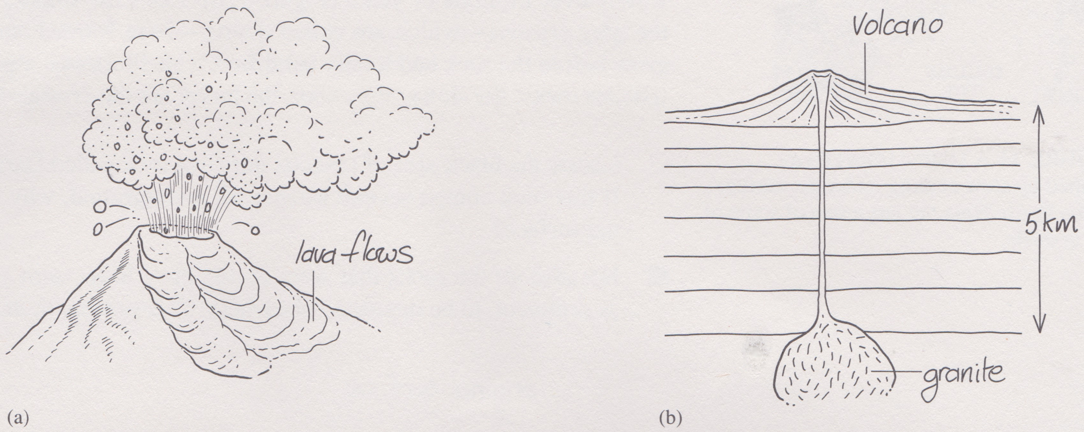


FIGURE 12 (a) Rocks formed when lava is forced out on to the Earth's surface from a volcano are called extrusive rocks. (b) Rocks that form where magmas cool deep underground are called intrusive rocks.

Look at the areas on the map that indicate igneous rocks—solid for intrusive or v v v for volcanic rocks.

□ Locate an area showing volcanic rocks.

■ You might have found a large area in Northern Ireland that includes the Giant's Causeway (shown in Figure 13), or the islands off the west coast of Scotland. Any of the areas showing the v v v ornament are areas of volcanic rocks.

FIGURE 13 The Giant's Causeway, formed by the cooling of volcanic rock at the surface of the Earth.

FIGURE 14 A granite from Devon, formed by slow cooling under the surface of the Earth. Note the large size of some of the crystals.

Look at Figure 14, a **granite** from a quarry on Dartmoor in South Devon. Here the whole rock is a tightly fitting interlocking mass of crystals. Three types of crystals are visible: large white ones, smaller grey ones, and small black ones. These crystals represent three different minerals. For now, it might be helpful to think of the rock as a fruit salad, and the minerals as the individual pieces of melon, peach, pear, etc., of which the salad is made; sometimes it is easy to identify the fruits, sometimes it is not. Look again at the rock in Figure 14; as the liquid magma began to cool, the first crystals that started to grow were the large white ones, which had time to grow up to several centimetres long. This occurred many kilometres below the Earth's surface, as the magma cooled very slowly over millions of years (Figure 12b). Later the smaller, black flakes and the grey crystals—which are called quartz—were formed and had less time to grow before the rock had totally solidified. This illustrates a general principle of igneous rocks: the slower they cool, the larger are the crystals that are formed.

□ Locate the black area of igneous intrusive rock called Dartmoor on the map. If this rock cooled several kilometres underground, why is it now found at the surface?

■ Because all the rocks that were on top have been worn away and removed as sediment, to be deposited elsewhere. This process is shown in Figure 15.

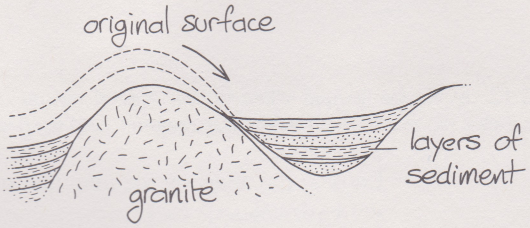


FIGURE 15 Overlying rocks are removed and deposited elsewhere as sediment.

Igneous rocks, such as granite, take an excellent polish, so they are quarried for use as decorative shop-fronts. They are not often used for houses because they are more difficult to cut than sedimentary rocks. There are always exceptions, such as the 'granite city' of Aberdeen, where the rock has been used in many buildings. Occasionally granite is used for non-domestic buildings, such as Dartmoor prison and Truro Cathedral, and as decorative 'setts' (square cobbles). and gravestones. It was widely used for making kerbstones in Victorian times, so if your home town has parts that were built during the last century you may find granite kerbstones (look for the large white crystals). If you are lucky enough to live in Milton Keynes, you will be aware that a great deal of polished granite (from Cornwall) has been used in road cuttings and pedestrian underpasses as a decorative facing stone.

The characteristic hardness of igneous rocks (they are often called 'hard rocks') makes them a very useful material. They are resistant to crushing and constant rubbing (by car tyres, for example) and so are in great demand as a material with which to construct roads. They provide the ballast for railway tracks, and, broken up into small chippings, are used to make strong concrete for main drainage and sewage pipes. If you imagine what our lives would be like without roads and drainage you should be able to appreciate how important igneous rocks are to us.

SAQ 4 Which phrases have you highlighted that relate to the formation and nature of igneous rocks? Check your list against ours at the back of the Module.

3.4 METAMORPHIC ROCKS

The third group of rocks is called metamorphic, a word that means 'changed form'. Both sedimentary and igneous rocks can undergo alteration and become metamorphic rocks. This happens if rocks are heated to temperatures of several

hundred degrees, especially when high pressure is involved (because of the weight of the overlying material). Sedimentary rocks are most easily changed or metamorphosed under these conditions. The material making up the rock reorganizes itself, sometimes resulting in the growth of existing minerals (crystals), or in the formation of new ones. This process is called **recrystallization**, and can often be seen as banding or alignment of the crystals in the rock.

Imagine a box of matches emptied on to a table, shown in Figure 16a. What would happen if you were to bring together two rulers, one on each side of the matches? You would find that all the matches would line up parallel to the rulers, shown in Figure 16b. The application of pressure (bringing together the rulers) has changed the random orientation of the matches so that they are now aligned, at right angles to the pressure.

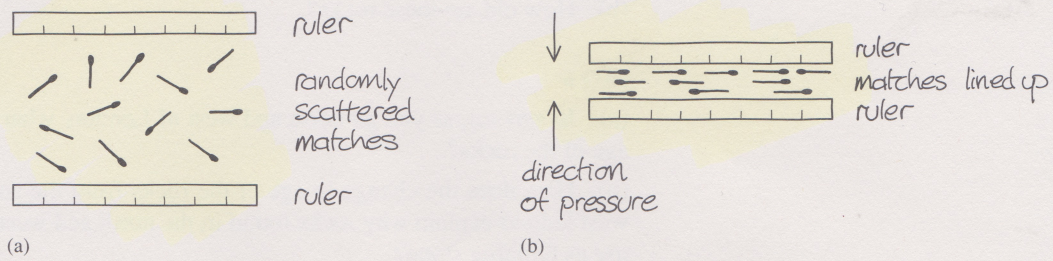


FIGURE 16 (a) A scattering of matches, representing the random orientation of grains in a sedimentary rock. (b) The application of pressure makes the matches line up at right angles to the pressure.

Rocks can be heated (baked) without involving an increase in pressure, for example, by being close to a hot magma near the Earth's surface. A useful analogy is that of baking a cake: a soft mixture goes into the oven and a firm solid comes out, but nothing has been added or taken away in the process (except a little water, which has been lost by evaporation). However, metamorphism due to pressure only, without heat, does not occur. This is because the tremendous pressure necessary to change a rock's structure occurs at great depth beneath the Earth's surface, and thus it is always accompanied by the higher temperatures that are found at these depths.

Rocks of any age can be metamorphosed by heat and some older rocks which have been buried deeply have been metamorphosed by pressure (accompanied by heat). All the oldest rocks represented on the map (600–3 000 million years old) have been metamorphosed and so are metamorphic.

Two metamorphic rocks that you may already know are:

Marble, a metamorphic rock formed from limestone. The metamorphism has made it much harder than limestone, and it has been in demand through the ages for making statues, and as a luxurious and durable building material.

Slate, a rock with an extremely fine grain size; it is difficult to make out individual crystals even with a hand lens or magnifying glass. It was originally laid down as a soft mud, but it has been recrystallized and the result is a hard, water-resistant rock that can be split into thin sheets.

Slates are found in North Wales and the Lake District where rocks are 395–570 million years old and also in Cornwall and Devon, where the rocks are 345–395 million years old.

Widely used as a roofing material, slate was a valuable commodity. During the eighteenth and nineteenth centuries slates were transported around the country; with practice you can learn to tell where materials used to make the roofs of our towns and cities came from. Welsh slates are characteristically grey-blue in colour, while Lake District slates often have a greenish tinge. Mass production of roof tiles made from clay and cement (by a sort of artificial metamorphism) has led to a severe decline in the use of slate for roofing, except in areas where it is common, such as North Wales and the Lake District.

In Section 3 you have learned that there are three different types of rocks: sedimentary, igneous and metamorphic; that rocks vary in age, from thousands of millions of years old, to rocks being formed at the present time; and that rocks vary in hardness and consequently in their suitability as building stone, or as raw materials in the building industry.

Most of the materials used in the construction industry come from the ground. In addition to building stone, bricks and slate, plaster is used for the internal walls, clay for ceramic tiles and sinks, and oil for plastics, such as your bath. The next Section moves on to discuss other aspects of buildings, such as size and shape.

SAQ 5 All of the oldest rocks in the UK have been subject to metamorphic processes.

(a) Where are these rocks found on the map?

(b) How old are these rocks?

SAQ 6

(a) In general, as you go north and west of London, what change is there in the age of the rocks?

(b) How does the change in age of the rocks from the south-east to the north-west help to explain why rocks found in the north and west are more suitable for use as building stone?

4 LOOKING AT YOUR HOME

This Section moves from buildings in general to a building that you are familiar with: your home. You will be considering aspects such as its size, shape and also the materials of which it is made, for example, can you estimate how many bricks were involved in its construction?

4.1 SIZE: INTRODUCING AREA

In the following Sections you will be asked to make some measurements on a room. You can use the measurements provided in the text to do the calculations, but you would find it useful practice to use your own measurements as well.

MEASURING THE SIZE OF A ROOM

In continental Europe, estate agents' descriptions of houses and flats always contain details of the overall **area** of the floor (known as floor area)—that is, the sizes of all the floors must be given. In the UK this information is not a requirement; you may have come across house details that give the maximum length and width of a room, measured into bay windows and alcoves, which can give a misleading impression of the true size of the room.

How can you work out the floor area of a square or **rectangular** space, such as a living room?

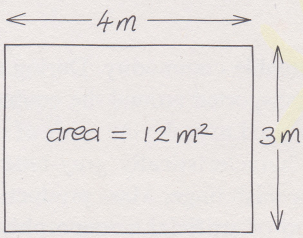


FIGURE 17 To calculate the area of a rectangle, multiply the length by the width

For squares and rectangles the area is found by multiplying the length in metres by the width in metres. The answer is given in square metres, which is abbreviated to m^2. This is shown in Figure 17.

□ What is the area of a room that measures $5.0\,m \times 5.0\,m$?

■ The area is 25 square metres, or $25\,m^2$.

If you know the area of a square, such as 25 m^2 as in the above ITQ, then you can work out the length of each side using the **square root.**

> The value of the square root is the number which, when multiplied by itself, results in n^2 (where n is the number).

In this case the square root is 5 since 5 × 5 is 25. Try the next one for yourself.

□ If a square has an area 16 m^2 what is the length of each side?

■ 4.0 m, as 4.0 × 4.0 = 16

Of course, if the 16 m^2 related to a rectangle you would not be able to work out the lengths of sides using the square root because the measurements for length and width would be different from each other. For shapes other than a square or rectangle, finding the area involves a little more thought.

□ Can you think of *two* ways of calculating the area of the room illustrated in Figure 18a?

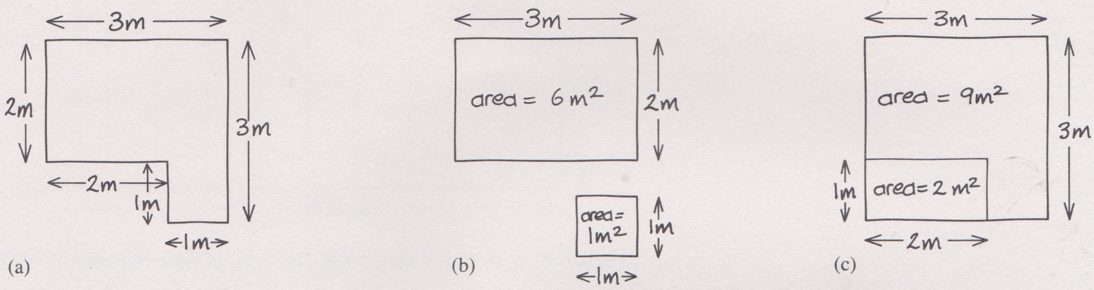


FIGURE 18 Calculating the area of an L-shaped room. (a) The L-shaped room. (b) The total area of the room is the sum of the areas of the two rectangles. (c) The total area of the room is the area of the large rectangle minus the area of the smaller rectangle.

■ You could think of the room as being made up of two rectangles, so that its total area is the sum of the areas of the two parts, as shown in Figure 18b. Or you could think of it as being a large rectangle, with a smaller rectangle taken out of it; the area of the room is given by the area of the large rectangle (3 m × 3 m) less (minus) that of the small rectangle (2 m × 1 m). This is shown in Figure 18c.

You could work out the area of the walls in a similar way; this might help you, for example, to calculate how much paint or wallpaper you would need to buy. Work through Guided Exercise 1, using some measurements that we have taken. Try to follow how the answers are calculated and then attempt SAQs 7–9 for yourself.

GUIDED EXERCISE 1: WORKING OUT THE AREA OF A WALL

We measured a wall that was 4.60 m long and 2.50 m high, so the area is:

4.60 m × 2.50 m = 11.5 square metres (abbreviated to m^2).

The calculator keys that you should press are shown in Box 1. Note that you do not need to key in the zeros that follow the digits after the decimal point, or before the decimal point if zero is the only number here. Thus for the number 0.048 0, you need only key in .048

BOX 1

Press	4	
press	•	
press	6	
press	×	
press	2	
press	•	
press	5	
press	=	(11.5 should appear)

BOX 2

Press	4	
press	•	
press	6	
press	÷	
press	•	(Remember, there is no need to press 0 before the decimal point)
press	5	
press	=	(9.2 should appear)

☐ Assume that rolls of wallpaper are 0.50 m wide. If you use a plain paper (so that there is no pattern to match up), how many vertical strips (drops) will you need to paper the wall we measured?

■ The calculator keys you should press are given in Box 2. We know that each roll is 0.50 m wide. If the wall is 4.60 m long, you will therefore need:

4.60 m ÷ 0.50 m = 9.2 vertical strips

Nine strips are clearly not enough; you will need a tenth strip cut vertically to fit, as shown in Figure 19.

☐ If a roll of wallpaper is 10 m long, how many rolls will you need to buy to get 10 strips?

■ To find the total length of wallpaper required, multiply the length of each strip by the number of strips. Each strip will be 2.50 m long (the height of the room), and you know from the preceding calculation that you need 10 strips. Therefore: 2.50 m × 10 = 25 m

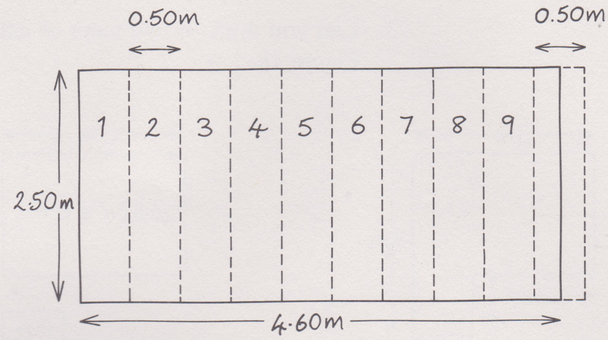


FIGURE 19 A wall 4.60 m long and 2.50 m high, papered by strips 0.50 m wide.

To find the total number of rolls required, divide the total length of wallpaper needed by the length of one roll, that is, 25 m ÷ 10 m = 2.5

You cannot buy half a roll of wallpaper, so you will need a total of three rolls to paper the wall.

Figure 20 gives the plan and side view of a rectangular house with some of its dimensions.

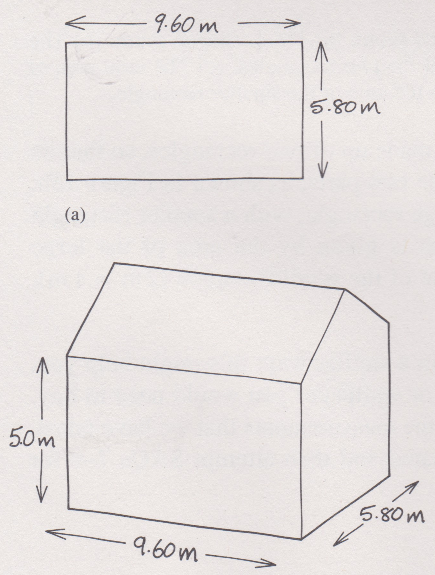


FIGURE 20 (a) Plan of a house. (b) Side view of a house.

SAQ 7

(a) Find the area of a long wall of the house in Figure 20.

(b) Measure the dimensions in metres of one wall, in a convenient room of your home, and work out the area of this wall. If you are unable to measure, try to make an estimate of the dimensions.

SAQ 8 Calculate the area of the ground floor of the house in Figure 20.

SAQ 9

(a) Calculate the number of rolls of wall paper needed to cover the long wall of the house in Figure 20 assuming the rolls are 0.50 m wide and 10.0 m long.

(b) Using the measurements you made in SAQ 7b, calculate how many rolls of wallpaper you would need to cover your wall.

4.2 WALLS MADE OF BRICKS

Most homes have bricks in their construction somewhere. Bricks are made from clay, which is shaped and then either left in the sun to harden (in hot, dry countries), or fired (baked) in a kiln. During firing water is driven off, resulting in some shrinkage, and the clay changes from a soft material that can be

moulded into shape, to a new, hard, brittle form. Sun-dried bricks do not attain the same degree of hardness and revert to soft clay after a prolonged soaking. The firing process is similar to baking cakes in an oven, or making pottery in a kiln, and is a sort of artificial metamorphism, similar to the processes described in Section 3.4.

Bricks have been a common building material in Britain for many years; after the Great Fire of London in 1666, the earliest known building regulations insisted that houses in London must be made mostly of brick or stone rather than timber, as these materials were less of a fire risk. Modern large-scale methods of brick-making mean that cheap bricks can be transported everywhere in Britain, so local materials, such as stone, are now used less.

□ Can you think of any other reason(s) why bricks are preferred to stone as a building material?

■ Bricks are regular in shape and of the same, or similar, size, so walls can be constructed rapidly and possess a uniform appearance. Although bricklaying is a skill, it is one that is relatively easily and quickly acquired, compared to that of working with stone. Rocks are irregular in size and shape, so building in stone is a very skilled activity. Walls of stone take longer to build and so are more expensive.

We are going to work out how many bricks there are in a wall. This involves measuring a brick and you should be aware that they may vary slightly in size.

□ Is it sufficient to base the calculation on the measurement of one brick only?

■ No, it is good scientific practice to measure several bricks, in order to work out the measurements of an 'average brick'. You were introduced to the idea of an average in Module 2.

□ What units could be used to measure a brick?

■ Millimetres or metres could be used.

Sometimes it is more convenient to use measurements that are not strictly SI, but are commonly used, for example centimetres (cm). Most rulers and measuring tapes are marked in centimetres.

□ From Module 2 you know that 1 m = 1 000 mm. If 1 m = 100 cm, how many millimetres are there in a centimetre?

■ 10; 1 000 mm = 100 cm therefore 10 mm = 1 cm, as 1 000 ÷ 100 = 10.

We are going to measure in centimetres.

The first brick measured was 21.5 cm long and 6.50 cm high. Measuring the thickness (or width) raised a slight problem, as the brick was cemented in a wall; however, we measured one on a corner, where its thickness could be seen. The width of the brick was 9.50 cm. Three more bricks were measured, and the results entered into Table 1.

TABLE 1 The measurements of some bricks

	Length/cm	Height/cm	Width/cm
brick 1	21.5	6.50	9.50
brick 2	21.4	6.60	9.40
brick 3	21.4	6.40	9.60
brick 4	21.5	6.50	9.50
average			
average to … sig figs			

☐ Calculate the average length, height and width, to an appropriate number of significant figures.

■ The averages are given in the table below.

average	21.45	6.50	9.50
average to 3 sig figs	21.5	6.50	9.50

As there are three significant figures in the data, the answer is also given to three significant figures i.e. 21.5 cm

☐ Change the average measurements of the brick from centimetres into metres.

■ There are 100 centimetres in 1 metre, so to convert centimetres into metres you divide by 100. The new measurements are:

length	21.5 cm ÷ 100 = 0.215 m
height	6.50 cm ÷ 100 = 0.065 0 m
width	9.50 cm ÷ 100 = 0.095 0 m

GUIDED EXERCISE 2: CALCULATING THE NUMBER OF BRICKS IN A WALL

We are going to look at ways in which the number of bricks in a wall can be worked out. Two such ways are given; you may find that one suits you better than the other. The final answer will be written as a whole number of bricks.

Assume the length of the wall is the same as that measured in Guided Exercise 1 (4.60 m), the height is 2.50 m; the average length of a brick is 0.215 m, and the average height of a brick is 0.0650 m. It is very important to note that when carrying out such exercises the units must be the same. Here the wall and brick measurements should both be in m or both be in cm.

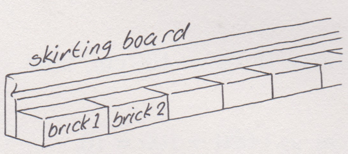
METHOD (a): USING LENGTH AND HEIGHT

☐ If bricks were laid end to end along a skirting board, as in Figure 21a, how many bricks would you need to make a row running the full length of the wall?

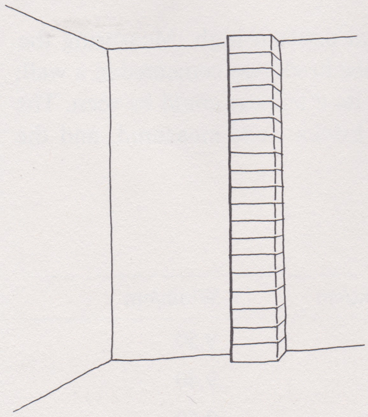
■ To obtain the number of bricks, divide the length of the room by the length of a brick. As the room is 4.60 m long, the calculation should be:

4.60 m ÷ 0.215 m = 21.395 348

Note that when you enter these figures into your calculator, the display shows as many digits as possible if the sum does not have an exact answer.



(a)



(b)

FIGURE 21 (a) A row of bricks along a skirting board. (b) A column of bricks from floor to ceiling.

☐ Now, if we were to balance bricks one on top of another, as shown in Figure 21b, how many bricks would be needed for the column to reach the ceiling?

■ This time you divide the height of the wall by the height of a brick. As the room is 2.50 m high, the calculation should be:

2.50 m ÷ 0.065 0 m = 38.461 538

This is the number of bricks needed for the column to reach the ceiling.

☐ So, if there are 21.395 348 bricks in a row and 38.461 538 rows, how many bricks are there in the wall?

■ In a similar way that the area of the wall was calculated in Guided Exercise 1, the number of bricks along the length of the wall is multiplied by the number of bricks in the column, that is:

21.395 348 × 38.461 538 = 822.897 99

To the nearest whole number (three significant figures), this becomes 823, so there are 823 bricks in the wall.

Note that we have rounded to an appropriate number of significant figures at the *end* of all the calculations, so as not to throw information away too early. In this way we increase the accuracy of the final answer.

METHOD (b): USING AREAS

□ Using the length and height measurements of the brick in metres, calculate the area of this face of the brick.

■ To calculate the area of this face of the brick you need to multiply the length by the height: $0.215\,\text{m} \times 0.065\,0\,\text{m} = 0.013\,975\,\text{m}^2$
The area is therefore $0.013\,975\,\text{m}^2$

In Guided Exercise 1, our wall was 4.60 m long and 2.50 m high, so the area was $11.5\,\text{m}^2$.

□ How many bricks, of area $0.013\,975\,\text{m}^2$ will fit into our wall? In other words, divide the area of the wall by the area of the brick. Give your answer as a whole number of bricks.

■ For our wall the answer is given by the following calculation:
$11.5\,\text{m}^2 \div 0.013\,975\,\text{m}^2 = 822.898\,03$

Therefore the number of bricks is 822.898 03. We need only express this to the nearest brick (i.e. whole number); therefore the number of bricks that will fit into a wall of this area is 823.

Again, we have completed the calculations before finally rounding to the appropriate number of significant figures. If you round to 3 significant figures after each step of the calculation you will find that the number of bricks differs slightly for the two methods of working.

4.3 CAVITY WALLS: INTRODUCING VOLUME

The outer walls of modern brick buildings are, in effect, double walls; they have an air gap, or cavity (see Figure 22), to prevent dampness penetrating the bricks and mortar, and also help to prevent heat getting out.

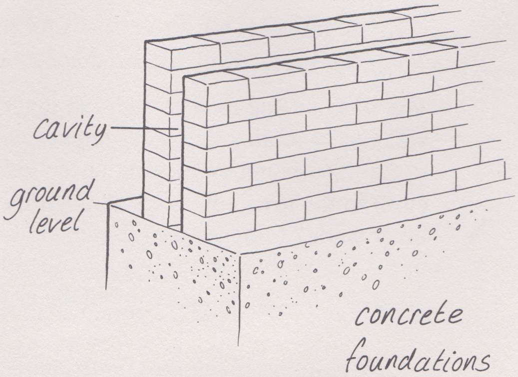


FIGURE 22 The construction of a cavity wall.

If you live in an older property (Victorian or earlier) the walls will probably be solid, but thicker than modern walls. Victorian walls are often 33 cm (13 inches) thick for the 'important' parts at the front of a house, but only 22.5 cm (9 inches) at the back and in the servants' quarters! (The measurements are given in Imperial units as well, because they would have been the units used in the original specifications for the houses; the SI system of units was not in use in the UK before the mid-twentieth century.) Stone buildings often have walls 60 cm or

more thick, with smooth stone faces on the outside and inside, but rubble in between. In other words, we need to consider not just the length and height of walls but also their width, because walls are three-dimensional, as shown in Figure 22.

How much material is used in the wall of a house? In other words, what is the *volume* of a wall? We will start by considering the volume of a brick, a rectangular solid.

> The **volume** of a rectangular solid is found by multiplying its length by its height by its width. This is shown in Figure 23.

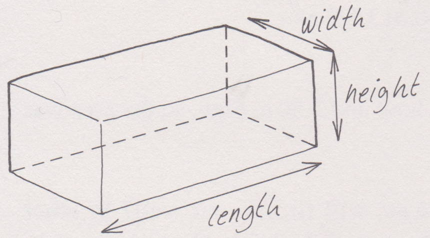


FIGURE 23 To calculate the volume of a rectangular solid, such as a brick, multiply the length by the height by the width.

For an object whose measurements are given in centimetres, the volume will be in cubic centimetres (abbreviated to cm^3); if the measurements are given in metres, then the volume will be in cubic metres (abbreviated to m^3).

□ Using the average measurements of the brick in Table 1, calculate the volume of a brick in cubic centimetres.

■ Using the formula: volume = length × height × width

The volume is as follows: $21.5\,m \times 6.50\,m \times 9.50\,m = 1\,327.625\,m^3$

Therefore the volume of an average brick is $1\,327.625\,cm^3$, or $1\,330\,cm^3$, to three significant figures.

SAQ 10 A building has an outer wall that is 30.8 m long, 4.50 m high and 9.50 cm thick. Calculate the number of bricks and volume of the wall of this building, by working through (a) to (c) below:

(a) What is the area of the outer wall? (Ignore the existence of any windows, doors, etc., to simplify the calculations.)

(b) Divide the area of the outer wall by the area of a brick ($0.013\,975\,m^2$) to obtain the number of bricks needed for the outer wall.

(c) Multiply the area of the wall by its thickness to obtain the volume (give your answer to three significant figures).

4.4 DIFFERENCES BETWEEN OUTER AND INNER WALLS: INTRODUCING DENSITY

Modern buildings often use bricks for the outer walls only. The inner skin of the cavity wall is made of blocks: this Section goes on to look at these.

The blocks used to construct the inner skin are larger than bricks; they allow walls to be built extremely quickly, and in addition they have properties that make them better at keeping in the heat. In some areas of France, for example close to the town of Volvic (known for its mineral water), and Italy, blocks for inner walls of houses are often made from loose volcanic ash. The composition of the ash is such that when it is mixed with water, pressed in moulds and then dried, the blocks harden without the use of commercial cement.

□ A building block measures length 44.0 cm; height 21.0 cm; width 8.0 cm. What do you notice about the volume of a block compared with a brick?

■ Volume of block = $44.0\,cm \times 21.0\,cm \times 8.00\,cm$

$= 7\,392\,cm^3$ or $7\,390\,cm^3$ to three significant figures.

The volume of a brick, from the previous Section is about $1\,330\,cm^3$. So, clearly the block is bigger.

□ How many times bigger is the block than the brick?

■ Divide the volume of the block by the volume of the brick

$7\,390\ \text{cm}^3 \div 1\,330\ \text{cm}^3 = 5.556\,390\,9$
or 5.56 times, to three significant figures.

Now to consider the mass of a block compared with that of a brick. (Mass was introduced in Module 1.)

□ A block registers 10.0 kg and a brick registers 3.50 kg on a pair of kitchen scales. Is the mass of the block 5.56 times that of a brick?

■ Clearly not, the mass of a block is only about three times that of a brick.

So, the conclusion is that the mass of the block is less than that of the brick *for the same volume*. The scientific term used to describe this property is **density.** You use this concept every day, for example to judge whether a cereal packet needs replacing, because a packet full of cereal is heavier than a packet full of air. Density is defined in the following way:

> the density of a substance is equal to the mass of the substance for a standard volume (e.g. one cubic metre).

or mathematically:

> Density = mass ÷ volume

□ A brick registers 3.25 kg, or 3 250 grams, on kitchen scales. (Recall that kilo means 1 000 so there are 1 000 g in a kilogram.) Its volume is $1\,330\ \text{cm}^3$. What is the density of brick in g per cm^3?

■ Density = mass ÷ volume

$= 3\,250\ \text{g} \div 1\,330\ \text{cm}^3 = 2.443\,609\ \text{g per cm}^3$

or 2.44 g per cm^3 (to three significant figures).

Try another calculation on density to test the idea that bricks are denser than building blocks.

□ The volume of a building block is $7390\ \text{cm}^3$. It registers 10.0 kg on kitchen scales. Calculate the density in g per cm^3 to an appropriate number of significant figures.

■ Density $= 10\,000\ \text{g} \div 7\,390\ \text{cm}^3 = 1.353\,179\,9\ \text{g per cm}^3$

or 1.35 g per cm^3 (to three significant figures).

By comparing the answers to the last two ITQs you can see that the blocks for the inner skin of the cavity wall are about half the density of the outer bricks.

SAQ 11

(a) Using the measurements you made in SAQ 7b, calculate the number blocks in the wall of your home. If you are unable to do this or for extra practice, use the measurements of the wall we measured in Guided Exercise 1 (4.60 m long by 2.50 m high). The dimensions of a block are 0.44 m long and 0.21 m wide. For practice use Method (a) on p. 16 in Guided Exercise 2.

(b) Calculate the volume of the wall made with blocks where the thickness is 0.080 m.

The next SAQ shows why ice floats. Make sure you read the answer.

SAQ 12 An ice cube made from tap water is 2.5 cm × 2.5 cm × 2.5 cm and its mass is 14.06 grams. What is the density of ice? (Answer to 2 significant figures.)

4.5 THE ROOF: INTRODUCING RIGHT ANGLES

In Britain roofs usually slope, to assist the run-off of rainfall. Flat roofs are common in hot countries where rain is rare, and in Mediterranean climates, roofs are frequently less steep. Some of these rooflines are shown in Figures 24a–d. For all of these buildings, if you know the width of the building, the height to the eave and the height to the ridge, then the length of the sloping roof can be calculated quite simply. This Section shows you how to do this.

☐ Can you recall the name and type of rock that was formerly used as a roofing material in this country?

■ Slate, a metamorphic rock.

The natural characteristics of slate mean that it can be split into very thin sheets, which makes it ideal as a roofing material. Slate splitting is a craft that has largely died out, however, and modern roofs are often made of manufactured tiles, mass produced as a cheap, uniform, easy-to-use product.

Other rocks have also been used for roofs, for example sandstones in Yorkshire. Although they could not be split as thinly as slate, they were useful nevertheless. Being thicker and heavier, however, sandstone roofs needed roof supports that were much stronger than those used for slate.

Suppose that you were faced with replacing some of the roof timbers of the house shown in Figure 24a.

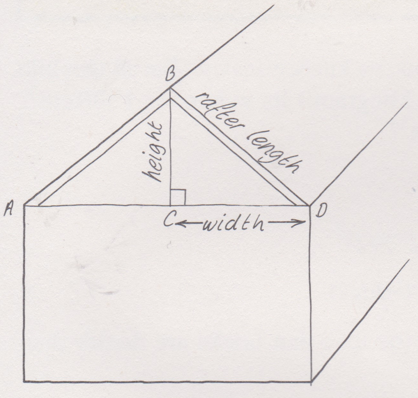


FIGURE 25 The gable of the house shown in Figure 24a.

☐ How would you find out how long they need to be?

■ In this case you could probably measure the length of the timbers directly.

But perhaps there are reasons why it is not feasible to measure existing timbers, for example if you are only at the stage of planning a building, so all you have are some drawings. How could you *calculate* how long the timbers need to be?

First, the problem is reduced to a triangle, that is a shape with three angles (and three sides). You can see that the shape in Figure 25 is the same as the side of the house shown in Figure 24a. The length marked height is the height of the ridge above that of the walls; width is half the width of the house; rafter length is the same in both figures. The important thing to notice is the symbol in the angle between the height and the width shown in Figure 25. This means right angle, or that the height is *perpendicular* to the width. You are probably aware of these terms in everyday life, in the context that walls are vertical and floors are horizontal and these two are 'perpendicular to each other' or 'at right angles'.

The names of the three sides of a right-angled triangle are given in Figure 26. Two of these you have already met, the horizontal and the perpendicular. The line opposite the right-angle is called the **hypotenuse**. It is useful to remember these three names.

Right-angled triangles are very important shapes that turn up in science frequently. It was Pythagoras, a Greek mathematician, who discovered the relationship between the sides of right-angled triangles, so it is known as 'Pythagoras' theorem'. It says:

> The square on the hypotenuse of a right-angled triangle is equal to the sum of the squares of the two other sides.

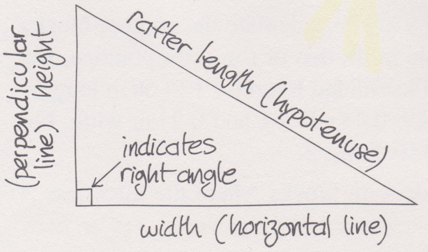


FIGURE 26 The triangle obtained from the gable of the house.

In mathematical form this is:

$$(\text{hypotenuse})^2 = (\text{perpendicular})^2 + (\text{horizontal})^2$$

or, in our case

$$(\text{rafter length})^2 = (\text{height})^2 + (\text{width})^2$$

You can use this mathematical formula to calculate the length of an unknown side of a right-angled triangle.

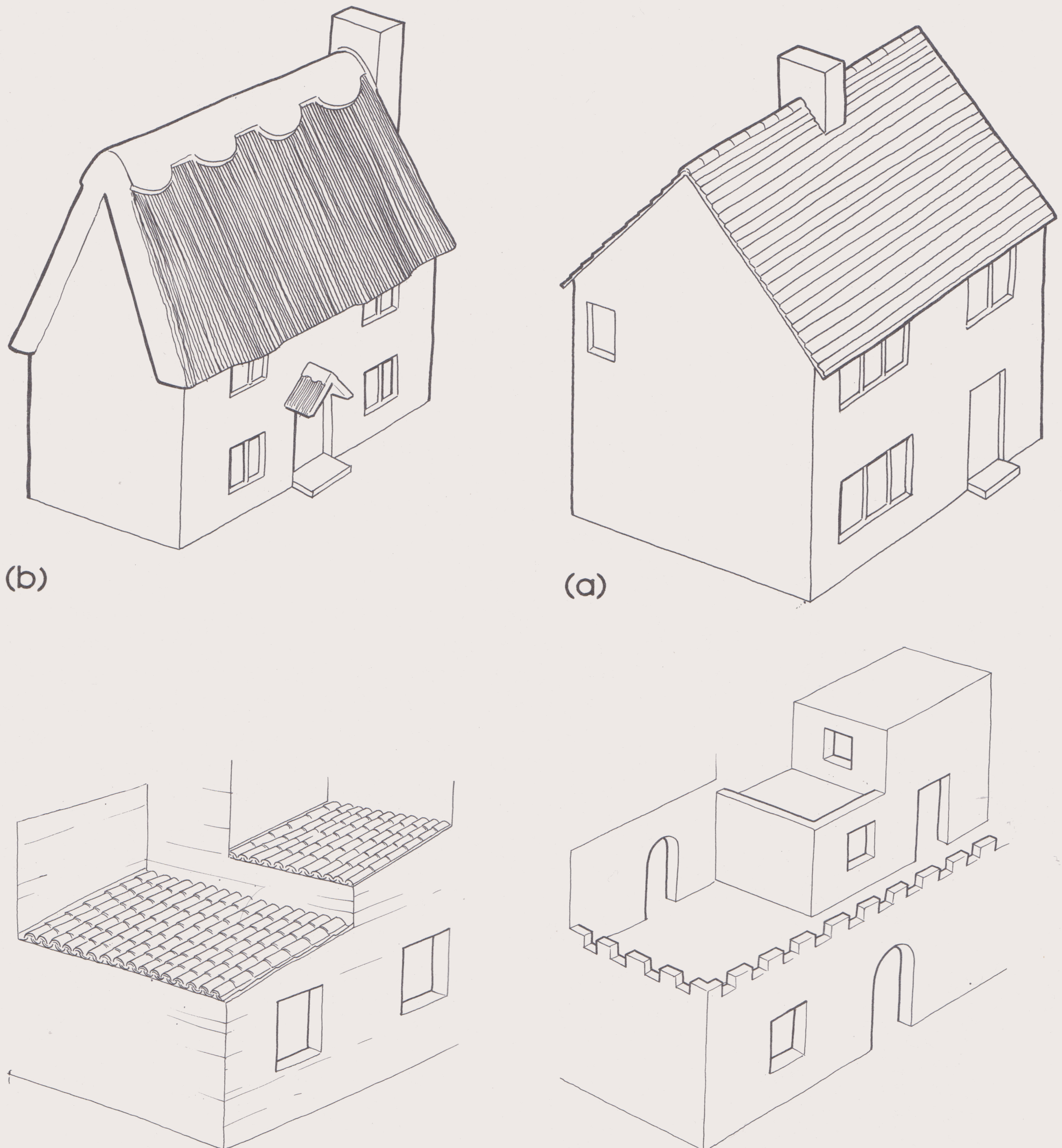


FIGURE 24 (a) The roofline of a typical British house (b) Steeply sloping thatched roof (c) Shallow pitched roof common in Mediterranean countries. (d) Flat roofs are common in the Middle East where rain is rare

□ The two sides of a right-angled triangle are 3.0 m and 4.0 m. What is the length of the hypotenuse?

■ $(\text{hypotenuse})^2 = (3.0\,\text{m})^2 + (4.0\,\text{m})^2$

$(\text{hypotenuse})^2 = 9\,\text{m}^2 + 16\,\text{m}^2 = 25\,\text{m}^2$

Now, you know from the previous work in Section 4.1 that finding the square root is the 'opposite' of finding the square of a number. Recall that square root just means that you need to find the number that, when multiplied by itself gives its square. Now, for numbers like 25, 16 or 9, this is relatively easy.

For other numbers it is less easy, so the calculator takes the strain. Try an easy one first—the calculation in the above ITQ. To find the square of 3 you enter 3, followed by $\times^2$ button; 9 should appear. Similarly for 4 press 4, followed by $\times^2$, 16 should appear. To find the square root of 25 find the button marked √ (meaning square root). Pressing this should result in 5.

So, the rafter length is 5. The full calculation is shown in Box 3.

BOX 3

Press	3	
press	$\times^2$	(9 should appear)
press	+	
press	4	
press	$\times^2$	(16 should appear)
press	=	(25 should appear)
press	√	(5 should appear)

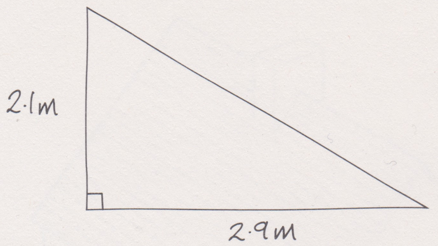


FIGURE 27 A triangle to calculate the length of the rafters.

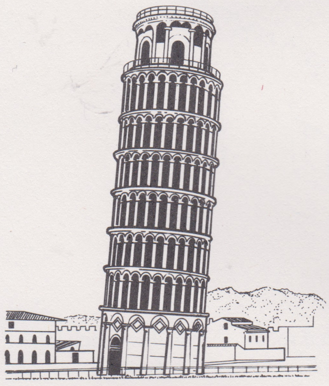


FIGURE 28 Leaning Tower of Pisa.

□ If the measurements of the triangle are as those in Figure 27, calculate the rafter length.

■ $(\text{rafter length})^2 = (2.1\,\text{m})^2 + (2.9\,\text{m})^2$

$(\text{rafter length})^2 = 4.41 + 8.41 = 12.82\,\text{m}^2$

So, to find the length of the rafter we take the *square root* of 12.82. Pressing the button marked $\sqrt{}$ should result in 3.580 502 8 being displayed.

You can check that no keying error has occurred; the correct answer must lie between three and four, as 3 is the square root of 9, and 4 is the square root of 16. As 12.82 lies between 9 and 16, the square root of 12.82 must lie between 3 and 4. So, the hypotenuse of the triangle has length 3.6 m (to 2 significant figures).

Notice that, in all cases, the length of the hypotenuse is greater than the length of either of the other two sides. This is true for all right-angled triangles. Pythagoras' theorem can also be used to find, for example, the vertical height, if the lengths of the hypotenuse and width are known. This is covered in a later Module.

This completes our work on the size and shape of buildings and some of the materials of which they are made. After you have completed the SAQs you should begin to appreciate the volumes of brick or stone involved in just one building—your home. If you were to multiply this by the buildings in one street, and the number of streets in your town or city, you will begin to see why there are large holes or quarries in some parts of this country, needed to provide the raw materials for the building industry.

SAQ 13 The Italian philosopher Galileo used a tower in Pisa to do experiments with falling objects. As it was built it began to lean, as shown in Figure 28. An object, dropped vertically, fell 19.7 m from the gallery and hit the ground 3.47 m out from the wall. What is the distance of the gallery from the base of the tower?

Hint: draw a triangle, mark the distances you know and use Pythagoras' theorem to calculate the unknown distance.

5 OVERVIEW

SUMMARY

These are the concepts you have learnt about in this Module:

- There are three different types of rock: sedimentary; igneous; and metamorphic.
- Rocks are formed by different processes: sedimentary rocks are laid down as sediment, for example by rivers; igneous rocks are formed by the cooling of molten rock; metamorphic rocks are existing rocks that have changed form, by heat alone or heat and pressure.
- Rocks vary in age, from those that are thousands of millions of years old, to those that are being formed at the present time.
- Rocks vary in hardness, and consequently in their suitability as building stone, or as raw materials in the building industry.
- Area (length × width); volume (length × width × height);

  density (mass ÷ volume);

  and Pythagoras' theorem: (hypotenuse^2 = perpendicular^2 + horizontal^2).

SKILLS

Now that you have completed this Module you should be able to:

- recognize areas of different rocks on a geological map, using the key
- calculate the area of squares and simple rectangles and the volume of cubes and rectangular solids
- calculate the density of a substance, by dividing the mass by the volume
- calculate the length of the hypotenuse of a right-angled triangle, using Pythagoras' theorem
- calculate a square root of a number, by using the √ key on a calculator.

APPENDIX 1: EXPLANATION OF TERMS USED

As you progress through the Modules you will meet some of these terms and concepts again and learn more about them.

AREA   A measurement of length × width, expressed in square metres (m^2).

CALCITE   A mineral composed of calcium carbonate, the main component of limestones.

CHALK   A variety of limestone that is a soft, white sedimentary rock. The Chalk that forms the White Cliffs was laid down 65–140 million years ago.

CLAY   A very fine-grained sedimentary rock that can be moulded to make pottery and bricks.

CRYSTALLIZATION   The process of forming a solid from a liquid rock (called magma), in which an interlocking mass of crystals is formed.

DENSITY   Density = mass ÷ volume—the mass of a substance per unit volume. A quantitative way of comparing how relatively heavy substances are. In this Module it is expressed in g per cm^3, but SI units kg per m^3.

FOSSIL   The remains of former life preserved in rock. It can be the remains of a plant or animal, or record of animal movement, e.g. a footprint or burrow.

GRANITE   A type of coarse-grained intrusive igneous rock, formed by slow cooling of magma beneath the Earth's surface.

HYPOTENUSE   The side in a right-angled triangle that faces the right-angle. It is longer than the two other sides.

IGNEOUS ROCK   A rock formed by the crystallization of hot liquid rock (magma). May be formed at the surface of the Earth or deep underground. *Extrusive* igneous rocks are formed by the extrusion (forcing out) of hot liquid rock on to the Earth's surface, usually from a volcano and hence cools very quickly. *Intrusive* igneous rocks are formed by crystallization deep underground so the magma cools very slowly.

LAVA   Hot liquid rock that comes out of a volcano.

LIMESTONE   A sedimentary rock formed from the remains of marine plants and animals and consisting of the mineral calcite.

MAGMA   Hot liquid rock. (When it flows on to the Earth's surface as a result of volcanic activity it is usually called lava, see above.)

MARBLE   A rock formed by the metamorphism of limestone and so made of calcite.

METAMORPHIC ROCK   A rock that has 'changed form'; an existing rock that has been changed (recrystallized), by heat and/or pressure to another form. Mud (rock), for example, can be metamorphosed into slate.

MINERALS   Naturally occurring substances of which rocks are made.

QUARTZ   A common rock-forming mineral, found in, for example, granite and sandstone.

RECRYSTALLIZATION   This process is involved during the formation of metamorphic rocks. The grains or crystals making up the rock reorganize themselves as a result of the heat and pressure they experience. The result is an interlocking crystalline texture, frequently accompanied by new mineral growth.

RECTANGLE   A four sided figure with right-angled corners and opposite sides of equal length.

ROCK   The substances of which the Earth is made. Can be of varying hardness; can be made of one mineral or several different minerals.

SANDSTONE A sedimentary rock composed largely of quartz grains.

SEDIMENTARY ROCK A rock that is formed from sediment that has been laid down, for example on a beach or river. The grains have subsequently been stuck together.

SLATE A fine-grained metamorphic rock, formed originally from mud. Easily split into thin sheets, it was used for roofing.

SQUARE ROOT The number that, when multiplied by itself results in n^2 (where n is the number). (Example: Two is the square root of four, because $2 \times 2 = 4$.)

VOLCANO A hill or mountain formed from lava or ash that has been forced out from inside the Earth on to its surface.

VOLUME A measurement of length × height × width, expressed in cubic centimetres (cm^3) or, in SI units, cubic metres (m^3).

SAQ ANSWERS AND COMMENTS

SAQ 1 There are no right or wrong answers to this question, but to give you an idea of what we considered to be important words and phrases, we would have highlighted the following:

In the first paragraph: 1 000 BC Midlands, south-east, built of timber; straw or turf roof on wooden framework; gaps…dried mud.

In the second paragraph: 1 000 BC, north and west stone; roof of stone or turf on wooden framework; stone field walls; stone walls, beds, furniture.

In the third paragraph: Romans, tile floors from clay, baked at high temperatures; bricks, roof tiles; mortar (sand and cement); local stone Hadrian's wall; roads paved with stone.

In the fourth paragraph: after the Romans timber and other natural materials; Middle Ages, important buildings of stone.

In the fifth paragraph: local stone, trade in foreign stone.

In the sixth paragraph: seventeenth century…local stone; brick was also popular in Midlands south and east, little good building stone.

SAQ 2 If you can, discuss your answer to this question with other students. If you live near Birmingham, the rocks are 195-280 million years old and sedimentary. If you live near Leeds, the rocks are sedimentary but older, 280–345 million years old.

SAQ 3

(a) The rocks are 140–195 million years old and are described as mainly limestones and clays.

(b) The rocks are 395–570 million years old and are described as mainly slates and sandstones.

SAQ 4 The following phrases are important factors in the formation and nature of igneous rocks. Where you see a series of dots, this indicates that some of the words between have not been highlighted, but the words before and after the dots are part of the same explanation.

formed by the cooling of hot liquid rock called magma; lava…from a volcano; cooling process called crystallization; lava contains…gas…rock containing gas bubbles.

Pumice is a volcanic rock.

no active volcanoes in Britain at present; igneous rocks…rare; extrusive…Earth's surface; granite…deep underground…intrusive.

granite…interlocking crystals; three types; minerals; large white ones…cms long…kilometres below Earth's surface…cooled very slowly…millions of years; smaller black flakes and grey crystals…quartz.

slower…cool…larger…crystals.

characteristic hardness…resistant to crushing…rubbing.

You may have highlighted other, additional phrases, which are important, for example in relation to the *use* of igneous rocks, but these phrases do not relate to the formation and nature of igneous rocks, so have not been included here.

SAQ 5

(a) These rocks are found in the Scottish Highlands and islands and the north-west of Ireland.

(b) They are very ancient: 600–3 000 million years old.

SAQ 6

(a) As you move away from London (and the south-east of England generally) the age of the rocks increases. In other words, the rocks in the north and west of Britain are in general older than those in the south and east.

(b) The older rocks of the north and west are generally harder and more durable, so they are more suitable for use as building stone. Soft sands and clays that crumble away are not suitable for building; these types of rock are more common in the south and east.

SAQ 7

(a) The area of the wall is $9.60\,\text{m} \times 5.00\,\text{m} = 48.0\,\text{m}^2$.

(b) We cannot provide a right answer. We suggest that you discuss the measurements you have made with other students.

SAQ 8 The area of the ground floor is:

$9.60\,\text{m} \times 5.80\,\text{m} = 55.68\,\text{m}^2$

$= 55.7\,\text{m}^2$ (to 3 significant figures).

SAQ 9

(a) The wall is $9.60\,\text{m}$ long $\div$ $0.50\,\text{m}$ strips

$= 19.2$ strips $= 20$ strips required

The wall is $5.00\,\text{m}$ high $\times 20 = 100\,\text{m}$

Since each roll is 10 m, then

$100\,\text{m} \div 10\,\text{m} = 10$ rolls.

(b) Having calculated your wallpaper needs, you should check that your answer is correct. As with other problems in science, there is a theoretical and a practical way of doing this. You could ask a fellow student, to check your calculations — perhaps offering to check your colleague's results in exchange.
The other, practical, way involves a pasting table, a pasting brush, a pot of wallpaper paste and the number of rolls of paper that you calculated! Good luck!

SAQ 10

(a) The outer walls of the building are 30.8 m long and 4.50 m high, so the total outer wall area is given by the calculation:

$30.8\,\text{m} \times 4.50\,\text{m} = 138.6\,\text{m}^2$

(b) The number of bricks needed is given by the calculation:

$138.6\,\text{m}^2 \div 0.013\,975\,\text{m}^2 = 9\,917.710\,1$

To the nearest whole number, 9 918 bricks are needed.

(c) Volume = area $\times$ thickness

$= 138.6\,\text{m}^2 \times 0.095\,\text{m} = 13.167\,\text{m}^3$

$= 13.2\,\text{m}^3$ (to 3 significant figures).

SAQ 11 The calculations below use the measurements of the wall we measured for Guided Exercise 1 (4.60 m long by 2.50 m high). Use the method to check your own measurements. Remember that you need to give all the measurements in the same units; we suggest metres.

(a) The number of blocks needed to extend the full length of the wall is given by dividing the length of the wall in metres by the length of a block in metres:

$$4.60\,\text{m} \div 0.44\,\text{m} = 10.454\,545\,45$$

The number of blocks needed to reach to the top of the wall is given by dividing the height of the wall in metres by the height of a block in metres:

$$2.50\,\text{m} \div 0.21\,\text{m} = 11.904\,761\,9$$

The total number of blocks needed is given by multiplying the total number of blocks needed for the length by the total number needed for the height:

$$10.454\,545\,45 \times 11.904\,761 = 124.458\,86$$

To the nearest whole number, a total of 124 blocks is needed.

(b) The volume of the wall is given by multiplying length by height by width:

$$4.60\,\text{m} \times 2.50\,\text{m} \times 0.080\,\text{m} = 0.920\,\text{m}^3$$

Therefore, the volume of the wall is $0.92\,\text{m}^3$ (to 2 significant figures, as the thickness was given to only 2 significant figures).

SAQ 12 Volume of ice cube

$$= 2.5\,\text{cm} \times 2.5\,\text{cm} \times 2.5\,\text{cm}$$

$$= 15.625\,\text{cm}^3$$

Density of ice

$$= \text{mass} \div \text{volume}$$

$$= 14.06\,\text{g} \div 15.625\,\text{cm}^3$$

$$= 0.899\,84\,\text{g per cm}^3$$

$$= 0.90\,\text{g per cm}^3 \text{ (to 2 significant figures).}$$

The density of tap water is $1.00\,\text{g per cm}^3$. This means that ice is about 10% less dense than water (which is why the ice cube floats, as less dense substances float on denser ones).

SAQ 13 Pythagoras' theorem states that

$$(\text{hypotenuse})^2 = (\text{height})^2 + (\text{width})^2$$

In this case the hypotenuse is the distance of the gallery to the ground, the perpendicular is 19.7 m and the horizontal is 3.47 m.

$$\text{So } (\text{hypotenuse})^2 = (19.7)^2\,\text{m}^2 + (3.47)^2\,\text{m}^2$$

$$(\text{hypotenuse})^2 = 388.09\,\text{m}^2 + 12.04\,\text{m}^2$$

$$(\text{hypotenuse})^2 = 400.13\,\text{m}^2$$

Taking the square root

$$\text{hypotenuse} = 20.0\,\text{m} \text{ (to 3 significant figures).}$$